Aalto University
School of Engineering

Modelling and Control of Water and wastewater treatment processes

WAT - E2130

Lecture 3 Influent fractions and nutrient removal

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Lecture outline

Guest lecturer

Sylvie Gillot INRAE -

Model calibration and validation

INFLUENT FRACTIONS

Wastewater and biomass fractions

Role of different fractions in models

EXERCISE WITH SUMO

HW2 Exercise 1

NUTRIENT REMOVAL

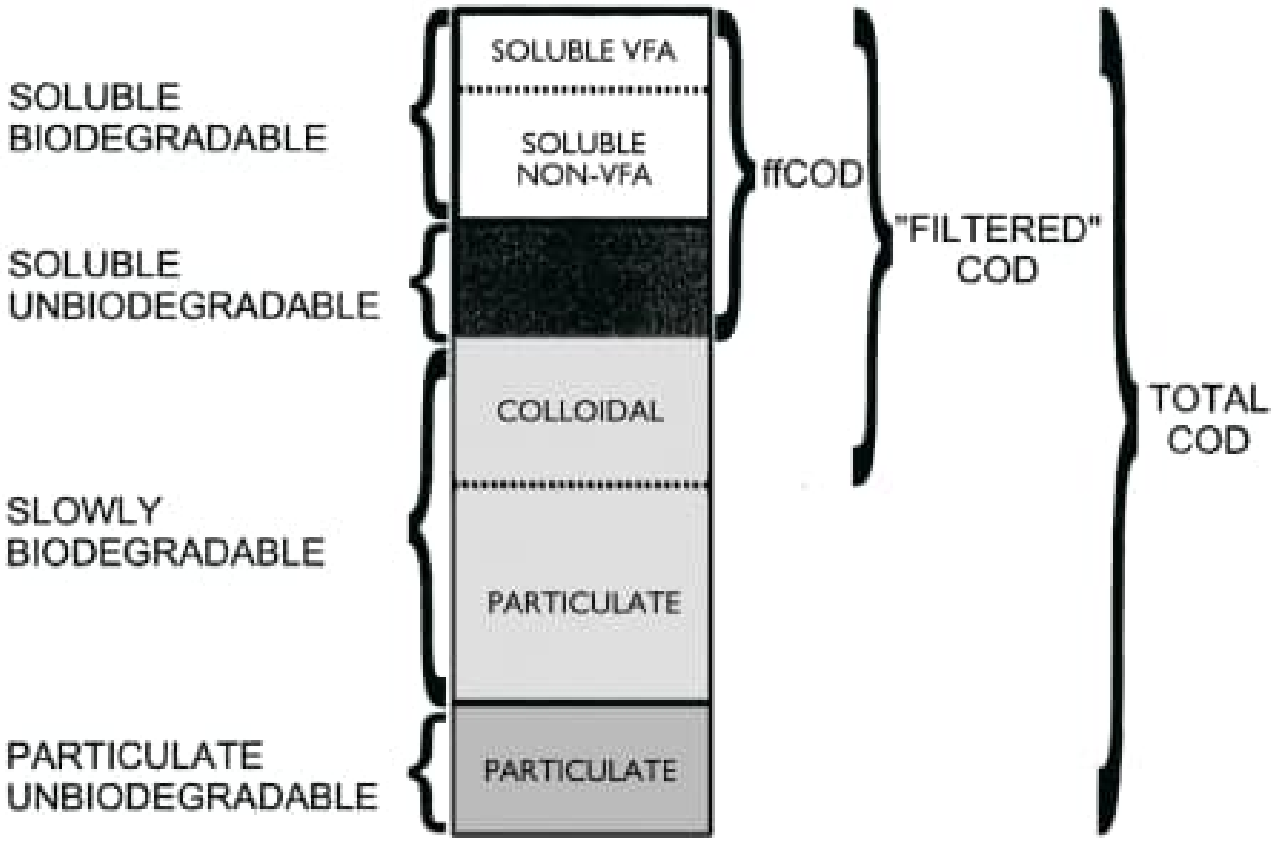
Nitrogen removal

Phosphorus removal

Anaerobic digestion

Instructions for the individual project work

Fractionation of COD



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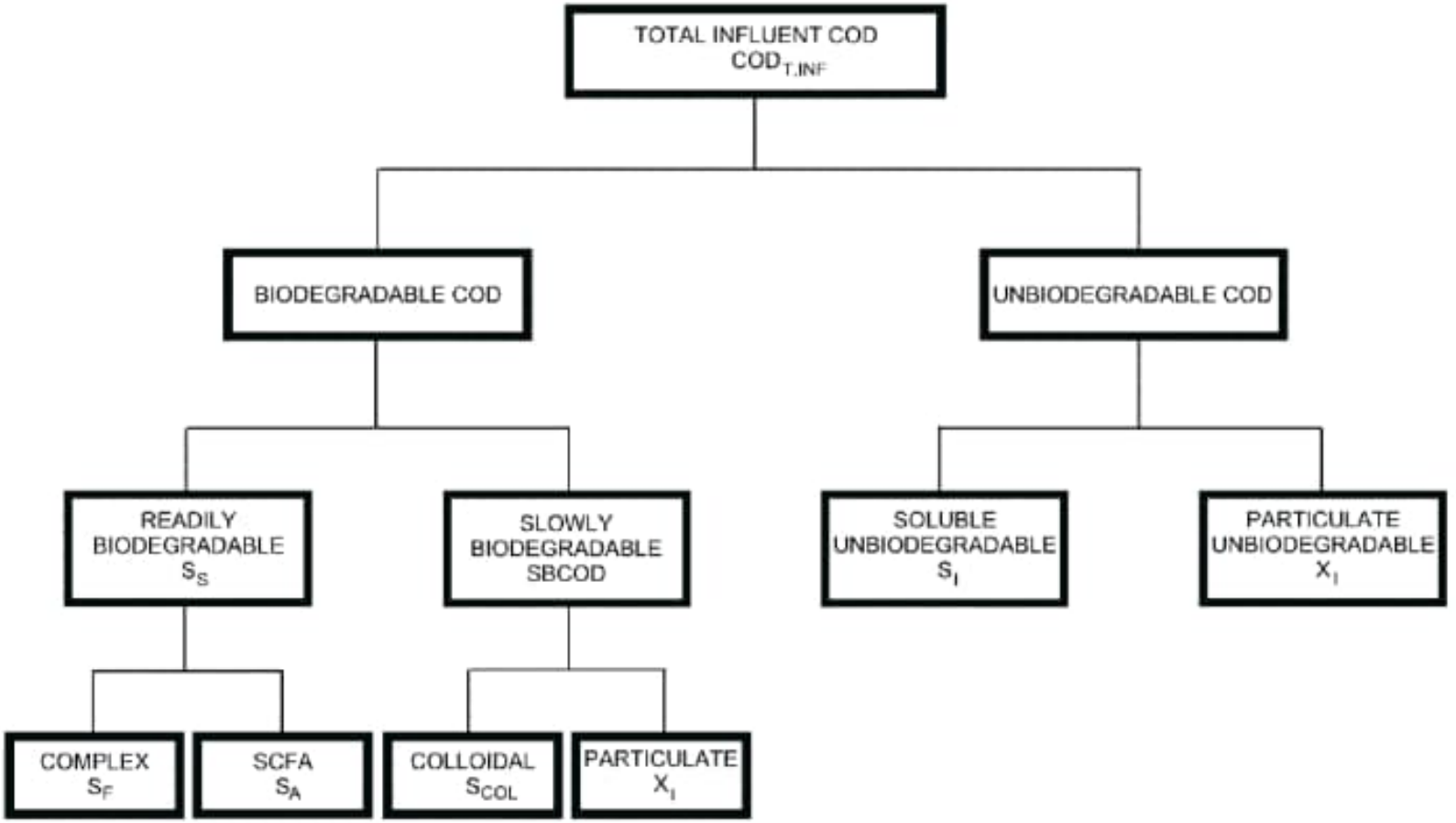
Organic matter



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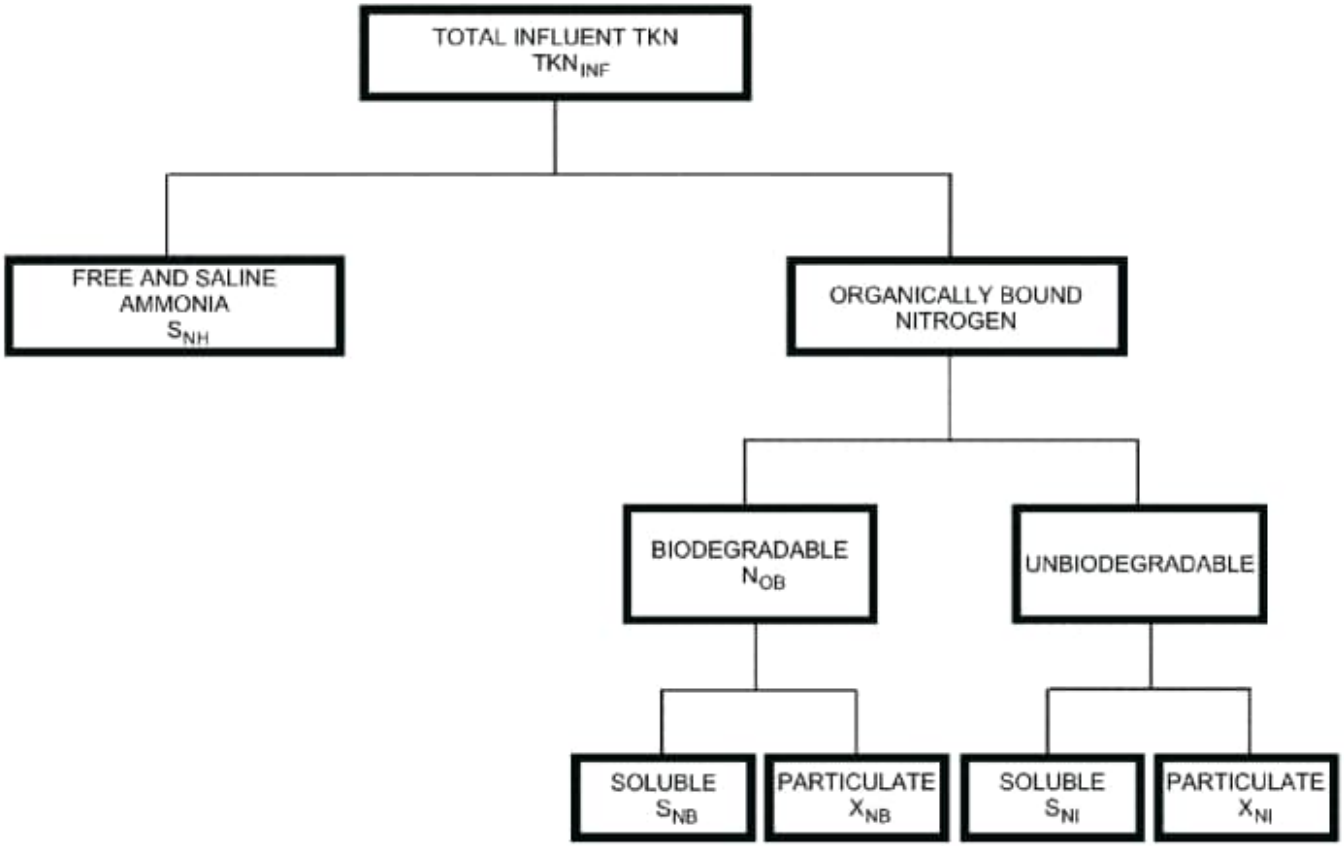
Nitrogen



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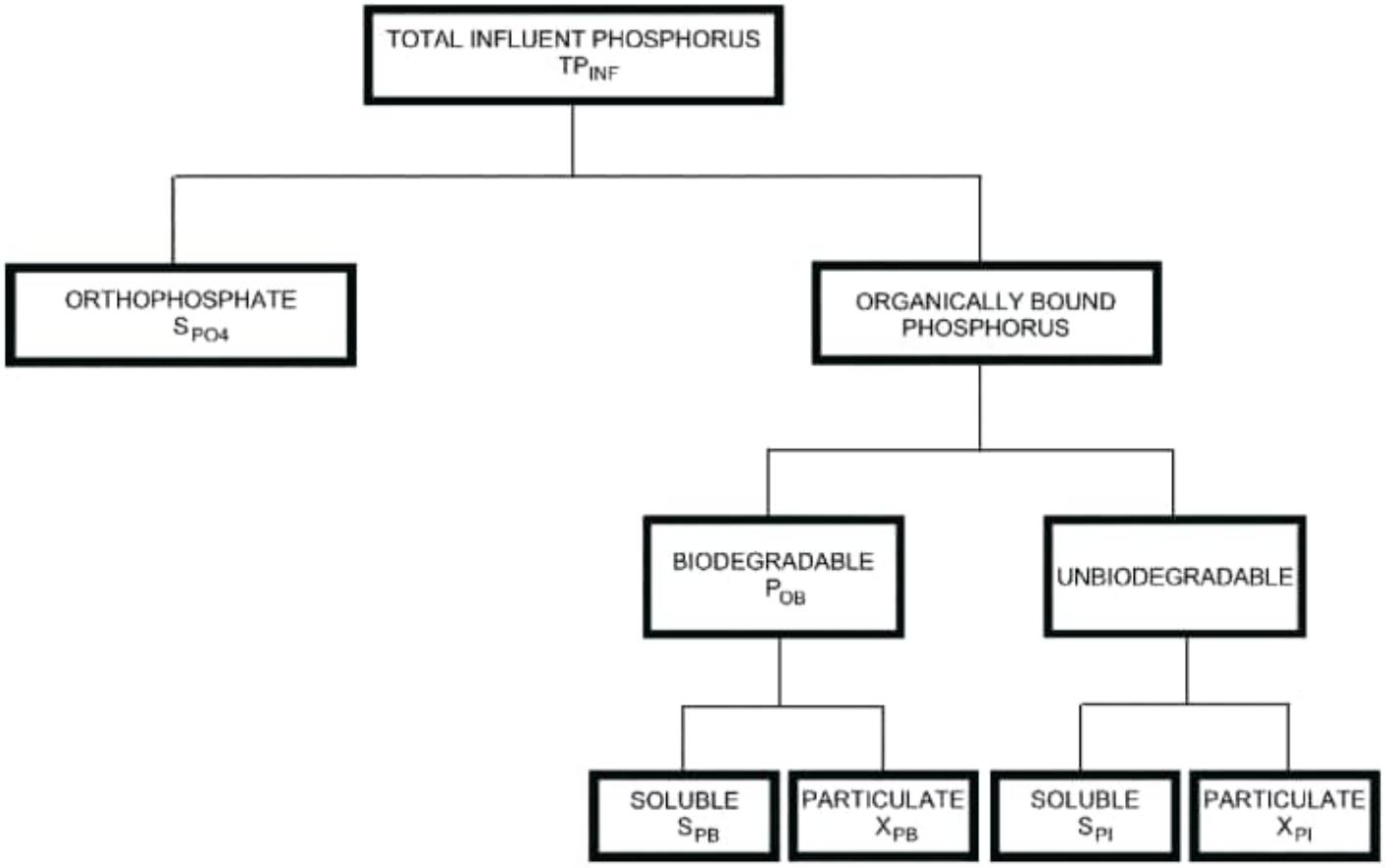
Phophorus



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Typical magnitudes of ww fractions

Table 4-2. Typical Municipal Wastewater Characteristic Parameter Values

Wastewater Characteristic	Concentrations	Concentration Units	Fractions	Fraction Units
Organic Material				
Total COD	250 – 700	g COD m^{-3}	–	–
Readily biodegradable COD	25 – 125	g COD m^{-3}	0.05 – 0.25	g COD / g of total COD
Soluble unbiodegradable COD	20 – 50	g COD m^{-3}	0.04 – 0.16	g COD / g of total COD
Particulate unbiodegradable COD	35 – 110	g COD m^{-3}	0.07 – 0.22	g COD / g of total COD
Slowly biodegradable COD	200 – 400	g COD m^{-3}	0.4 – 0.80	g COD / g of total COD
Nitrogenous Material				
TKN	25 – 70	g N m^{-3}	–	–
Free and saline ammonia	20 – 30	g N m^{-3}	0.50 – 0.75	g N / g TKN
Soluble unbiodegradable TKN	0 – 5	g N m^{-3}	0 – 0.07	g N / g TKN
Biodegradable organically bound TKN	0 – 10	g N m^{-3}	0 – 0.25	g N / g TKN
Particulate unbiodegradable TKN	2 – 8	g N m^{-3}	0.03 – 0.07	g N / g particulate unbiodegradable COD
Phosphorus Material				
TP	4 – 15	g P m^{-3}	–	–
Orthophosphate	2 – 12	g P m^{-3}	0.50 – 0.85	g P / g TP
Soluble unbiodegradable TP	0 – ?	g P m^{-3}	0 – ?	g P / g TP
Biodegradable organically bound TP	0 – 10	g P m^{-3}	0 – 0.25	g P / g TP
Particulate unbiodegradable TP	1 – 4	g P m^{-3}	0.02 – 0.03	g P / g particulate unbiodegradable COD

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Why is influent quality important?

- **Readily biodegradable organic matter**
  - Oxygen demand pattern
  - Determines process' ability to enhanced biological P removal
  - Level of denitrification achieved with wastewater's own carbon source
- **Unbiodergadable particulate COD**
  - Affects the oxygen demand
  - Affects the sludge yield

- **Influent quality also affects *e.g.* the performance of the primary clarifier**
- **Biggest differences with industrial wastewater**

Influent COD fractionation

- **TCOD** = $X_B + X_U + C_B + C_U + S_B + S_U$

  Particulate: $X_B + X_U$; Colloidal: $C_B + C_U$; Soluble: $S_B + S_U$
- **$FCOD_{1.2\mu m}$** = $C_B + C_U + S_B + S_U$
- **ffCOD** = $S_B + S_U$ ($ZnSO_4$ at 10 pH using NaOH)
- **RBCOD** = $ffCOD_{Influent} - ffCOD_{Final\ effluent}$

- (**OUR** for OHO determination)

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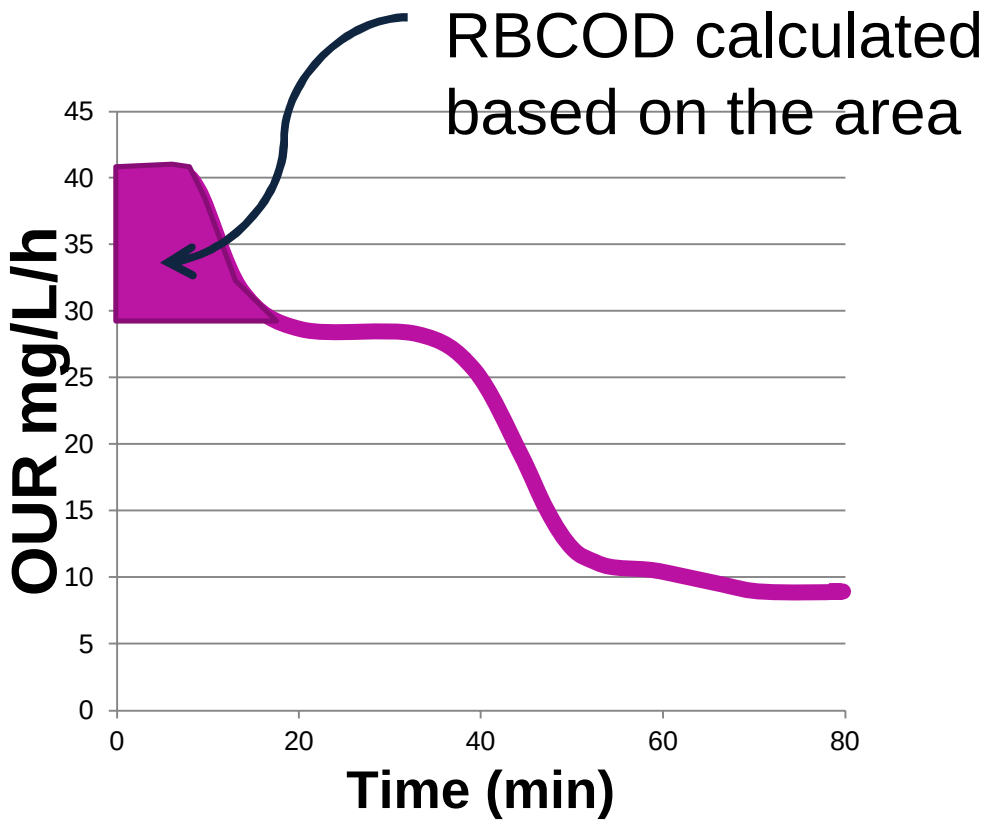
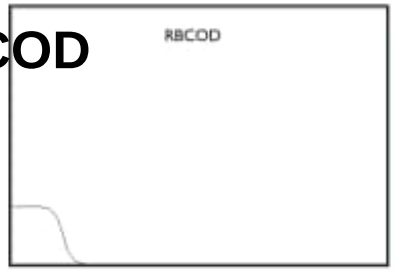
RBCOD measurement by respirometry

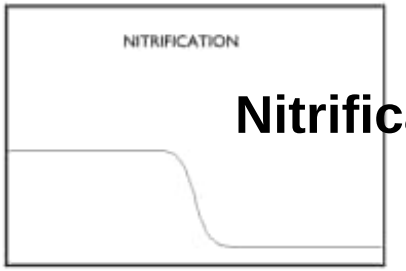
Respirogram



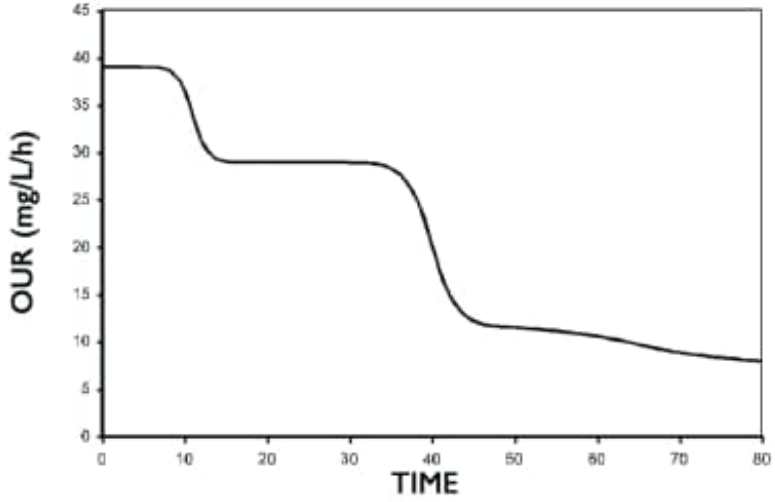
Components contributing to measured OUR

RBCOD

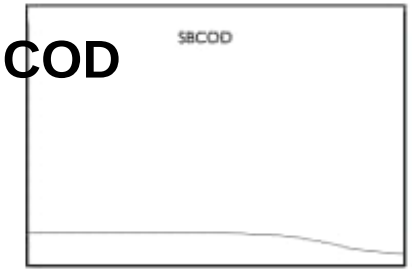


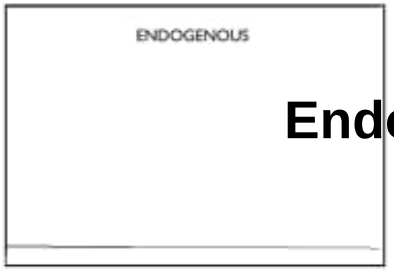


Nitrification



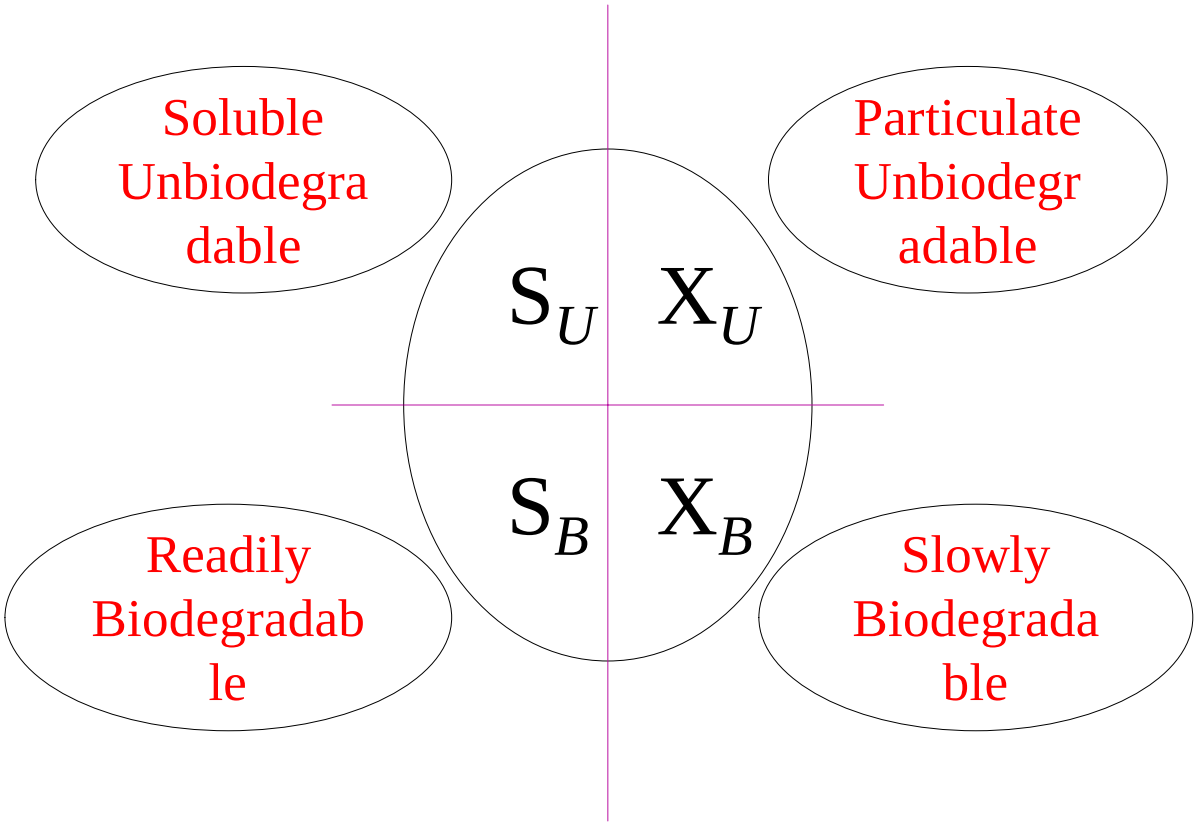
SBCOD





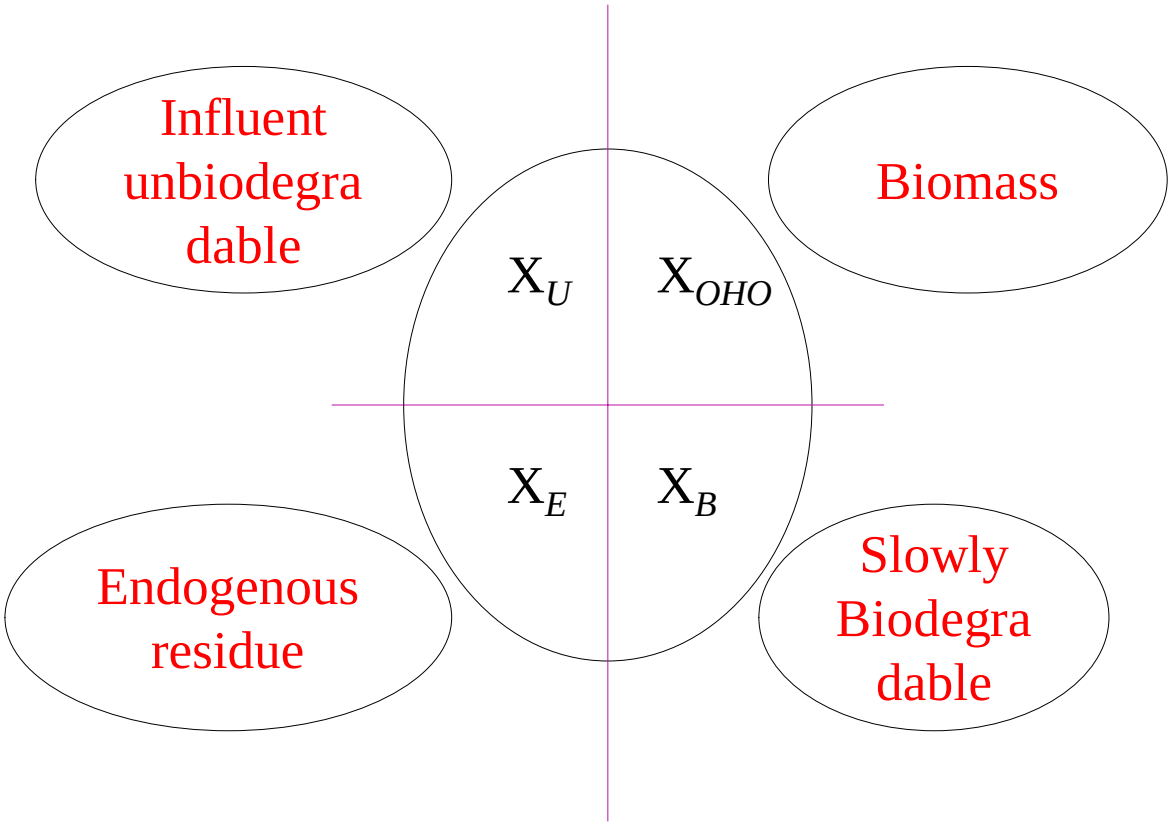
Endogenous

Activated Sludge Model No. 1 - Influent



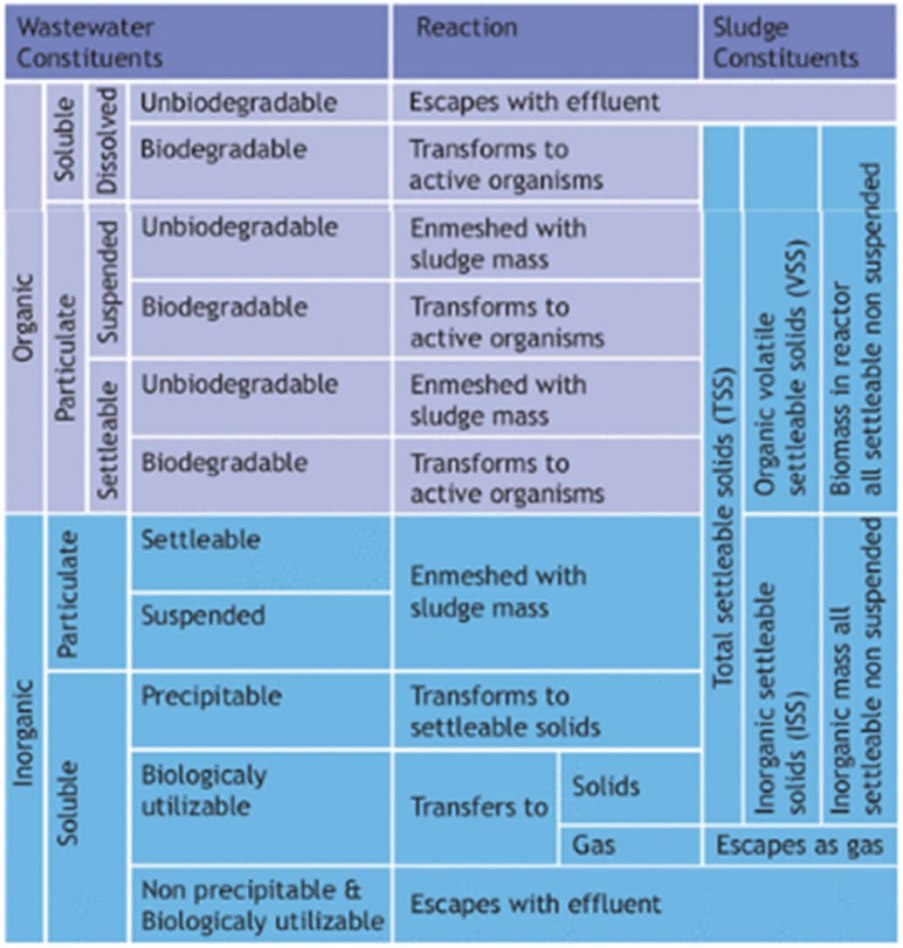
Four wastewater fractions, at least!

Activated Sludge Model No. 1 - MLSS



Four biomass fractions, at least!

Effect of the influent constituents



→ **ORGANIC MATTER**

→ BIODEGRADABLE – forms new biomass

→ UNBIODEGRADABLE

→ *PARTICULATE – goes to sludge*

→ *SOLUBLE – leaves with effluent*

→ **INORGANIC MATTER**

→ PARTICULATE – goes to sludge

→ SOLUBLE – precipitable

- Biologically utilizable
- The rest of the soluble inorganics escape with effluent

SUMO 1 Influent Fractions

S = soluble
C = colloidal
X = particulate
VFA = volatile fatty acid
B = biodegradable
U = unbiodegradable
OHO = ordinary heterotrophs
E = endogenous decay products
BIO = biomass

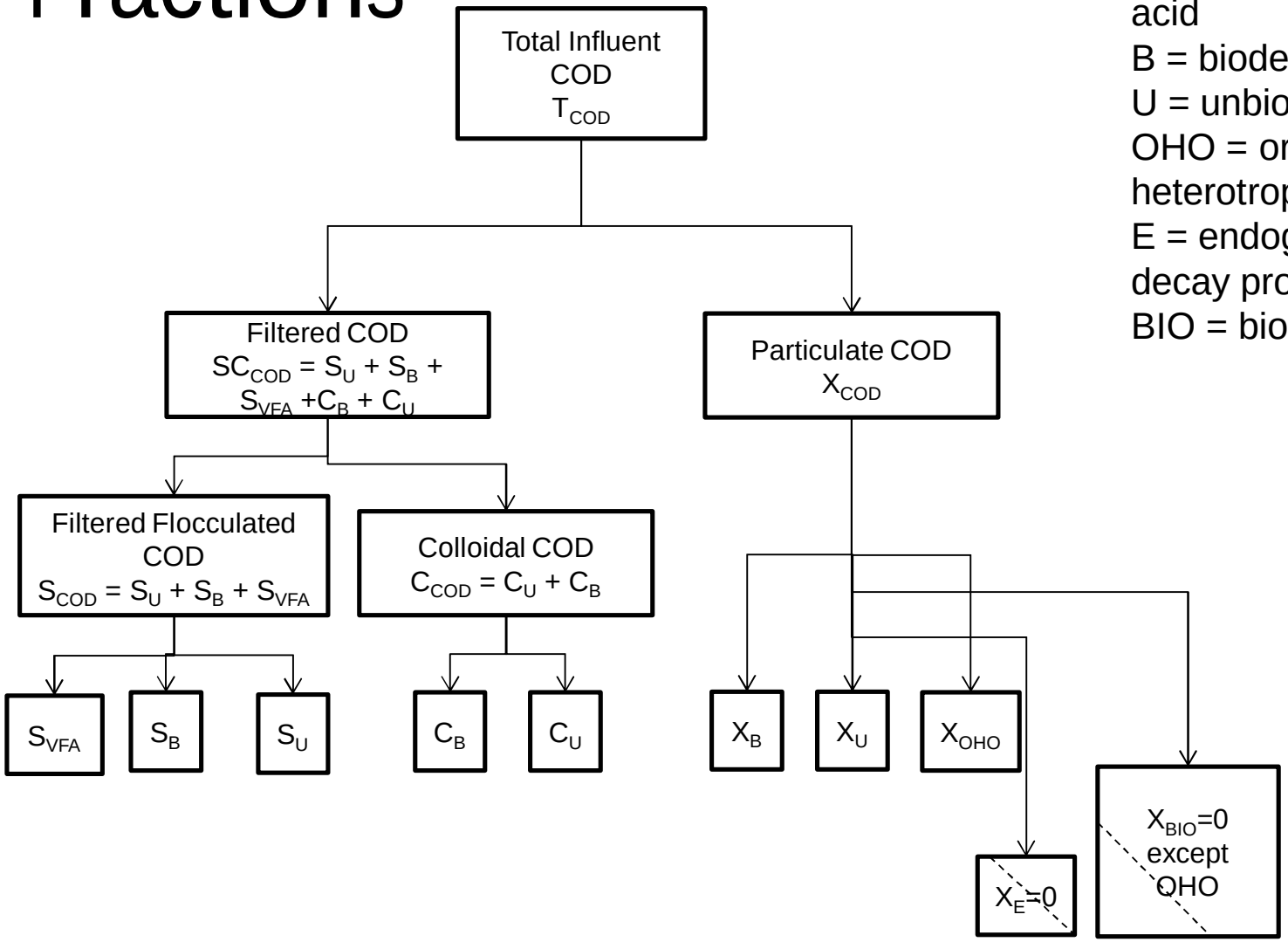


Table 6-2. Example Calculation of Particulate Unbiodegradable Portion of Influent VSS

Parameter	Concentration (mg/L)	Fraction	Fraction Units
Total COD	400		
Soluble unbiodegradable COD	20	0.05	(mg COD/mg total COD)
Soluble readily biodegradable COD	80	0.20	(mg COD/mg total COD)
Slowly biodegradable COD	248	0.62	(mg COD/mg total COD)
Particulate	186	0.75	(mg COD/mg SBCOD)
Colloidal	62	0.25	(mg COD/mg SBCOD)
Particulate unbiodegradable COD	52	0.13	(mg COD/mg total COD)
VSS*	149		
Particulate unbiodegradable portion of VSS**		0.22	

* VSS = (particulate slowly biodegradable COD + particulate unbiodegradable COD)/1.6

**Particulate unbiodegradable portion of VSS = Particulate unbiodegradable COD/1.6 /VSS

Note: These calculations assume a COD/VSS ratio of 1.6

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Sumo influent tool

Key measurements	Value	Unit
Flow	24000,0	MGD or m^3/d
TSS	185,0	mg/L
VSS	157,0	mg/L
TDM	800,0	mg/L
TKN	34,4	mg N/L
TP	4,3	mgP/L
Total Sulfur	20,0	mgS/L
Alkalinity	330,0	mg CaCO3/L
pH	7,2	-

Key indicators for sanity check	Value	Unit	Usual value in US
VSS/TSS fraction	**84,9**	%	85,00
Particulate COD/VSS	**1,59**	mg COD/mg VSS	1,60
Dissolved material	**615,0**	mg/L	
Alkalinity in molar units	**6,6**	meq/L	3 - 8

COD - BOD	Value	Unit
Influent COD	420,0	mg COD/L
Influent filtered COD	170,0	mg COD/L
Influent filtered flocculated COD	85,0	mg COD/L
Effluent filtered COD (inert)	20,0	mg COD/L
Influent $cBOD_5$	200,0	mg BOD/L

COD - BOD indicators for sanity check	Value	Unit	Usual value in US
Particulate COD	**250,00**	mg COD/L	
Filtered COD fraction	**40,5**	%	40,00
Filtered flocculated COD fraction	**20,2**	%	20,00
Unbiodegradable fraction of filtered COD	**11,8**	%	12 - 15
COD/BOD ratio	**2,10**	-	2,20
BOD/TSS ratio	**1,08**	-	1,10

Other influent measurements	Value	Unit
VFA	20,0	mg COD/L
Ammonia	24,0	mg N/L
Phosphate	2,5	mg P/L
Nitrite+nitrate	0,0	mg N/L
Calcium	150,0	mg/L
Magnesium	15,0	mg/L
Potassium	16,0	mg/L
Anions (expressed as chloride)	300,0	mg/L
Cations (expressed as Sodium)	110,0	mg/L

Other measurements indicators for sanity che	Value	Unit	Usual value in US
VFA fraction of filtered COD	**11,8**	%	10 -20
NH4 fraction of TKN	**69,8**	%	65 - 75
PO4 fraction of TP	**58,1**	%	50- 60
Other salts expressed as H_2CO_3 and NaCl	**431,5**	mg/L	100-300

Help | Data | Check fractions | Sumo forms | Fractionation tree | Balances | Diurnal flow | Birthday Cake | Calculations

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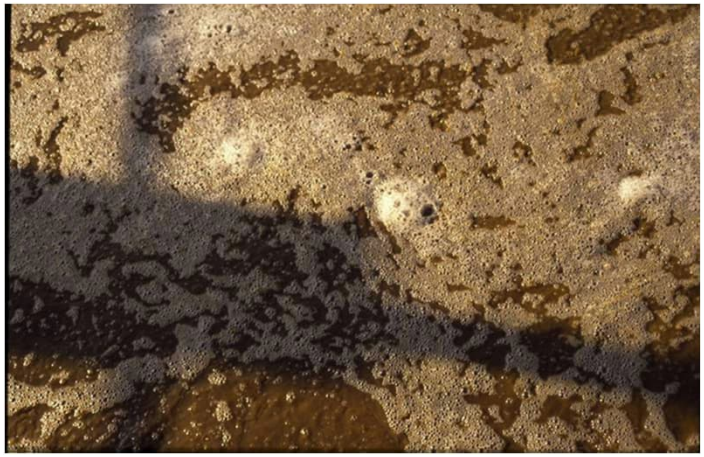
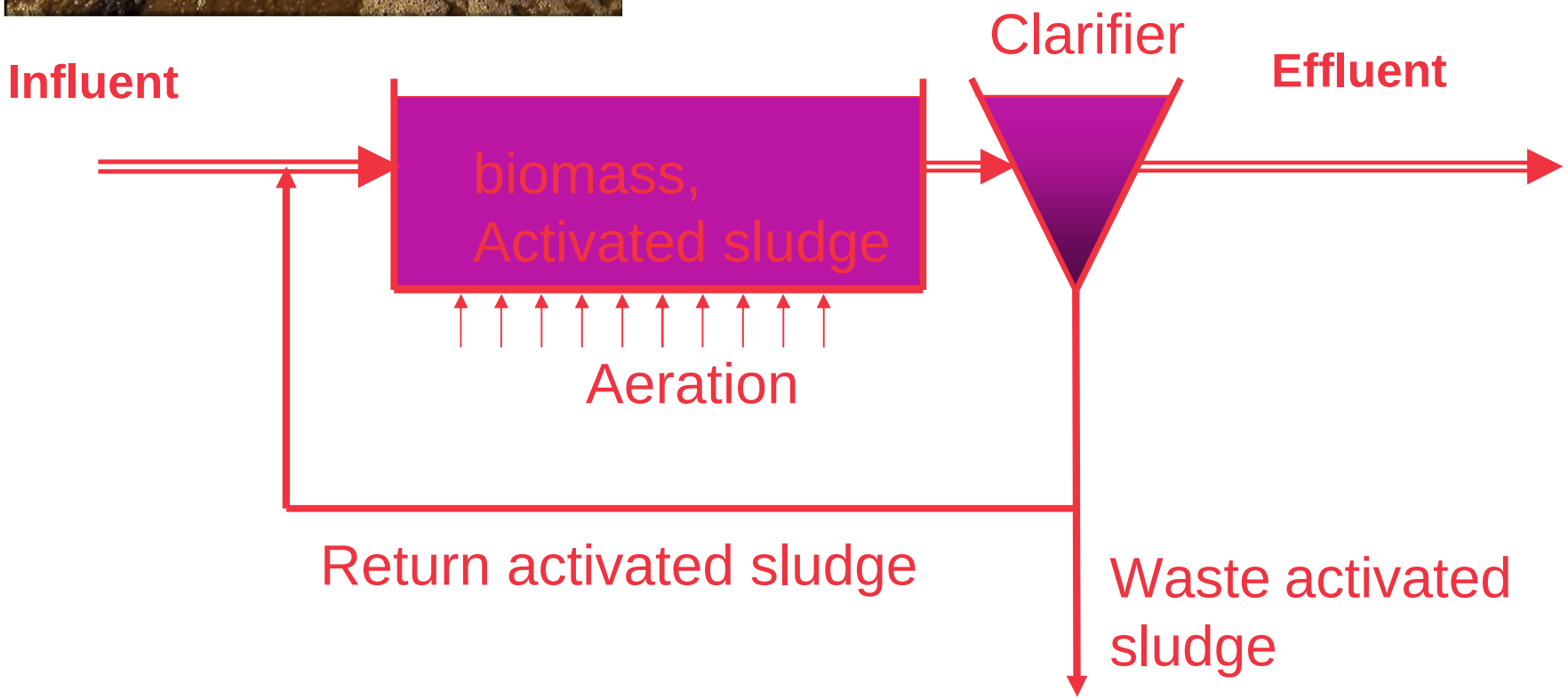
Biological processes
Nutrient removal

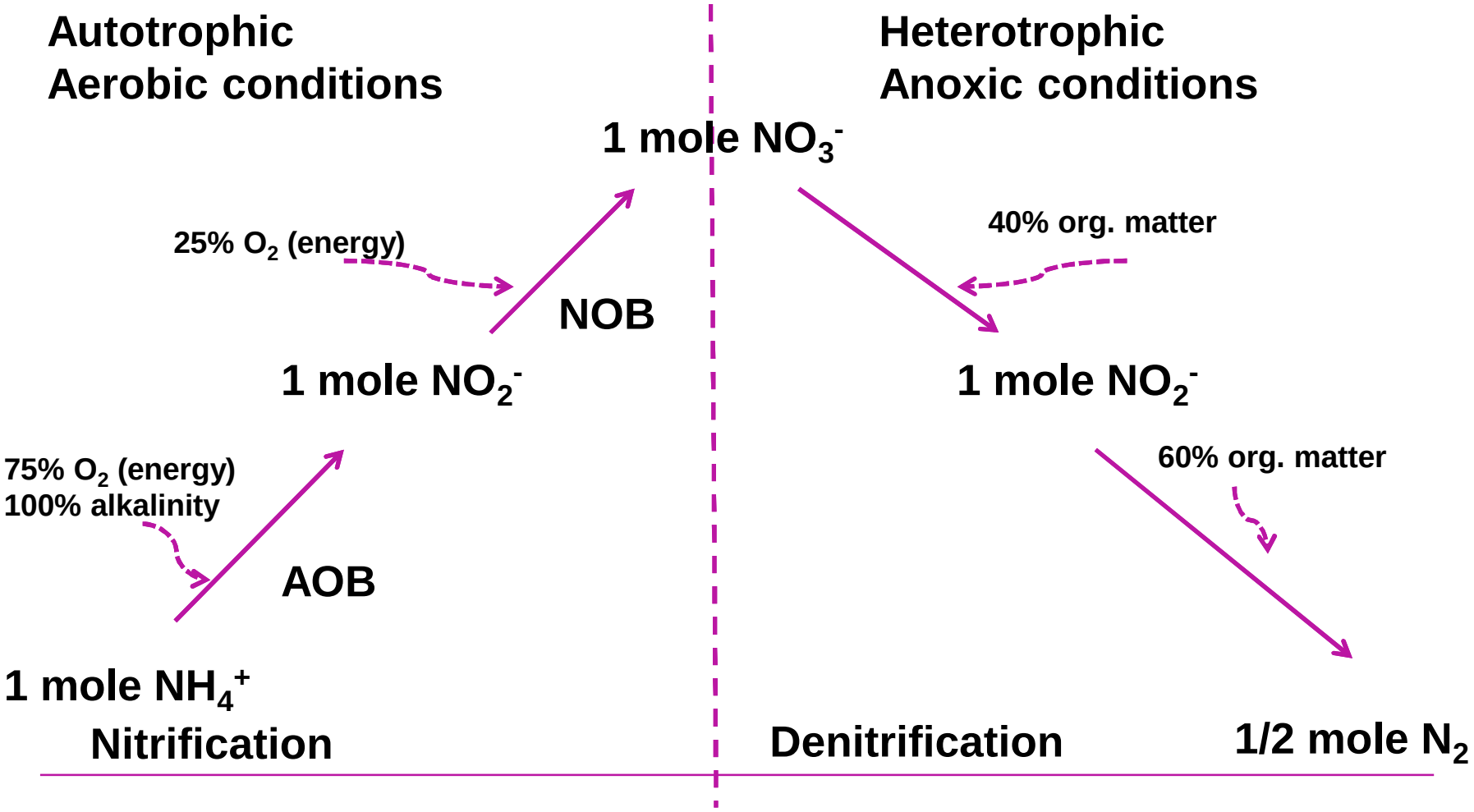
Anna Mikola



Activated sludge process



Conventional N removal



Nitrification and denitrification

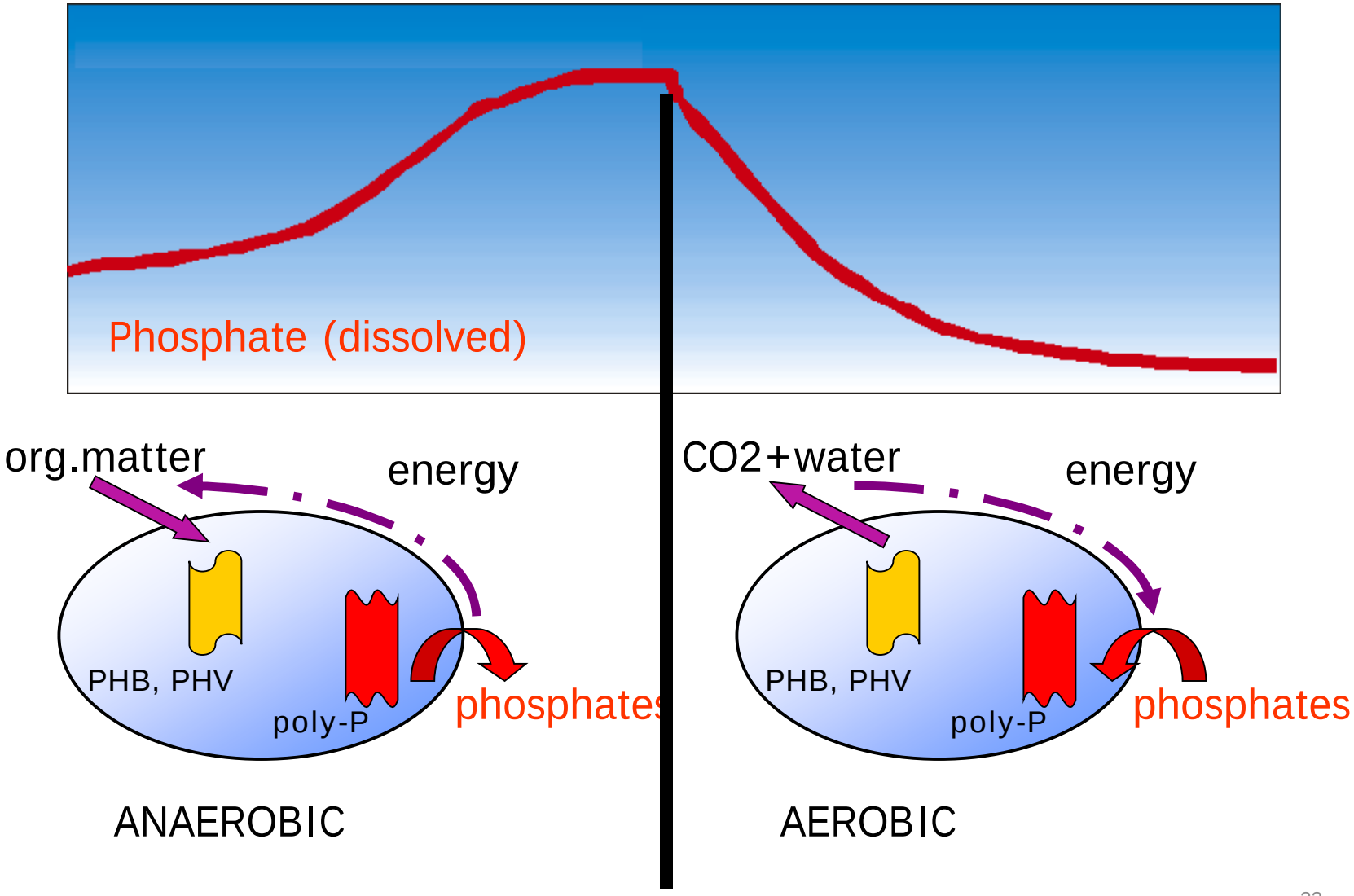
SRT	long SRT	short SRT increases the rate
Oxygen	high, 2 mg/l	no oxygen or very low
Organic matter	no need (autotrophic)	needs a carbon source
BOD load	low load	high load
Alkalinity	consumes	produces

Processes included in SUMO2

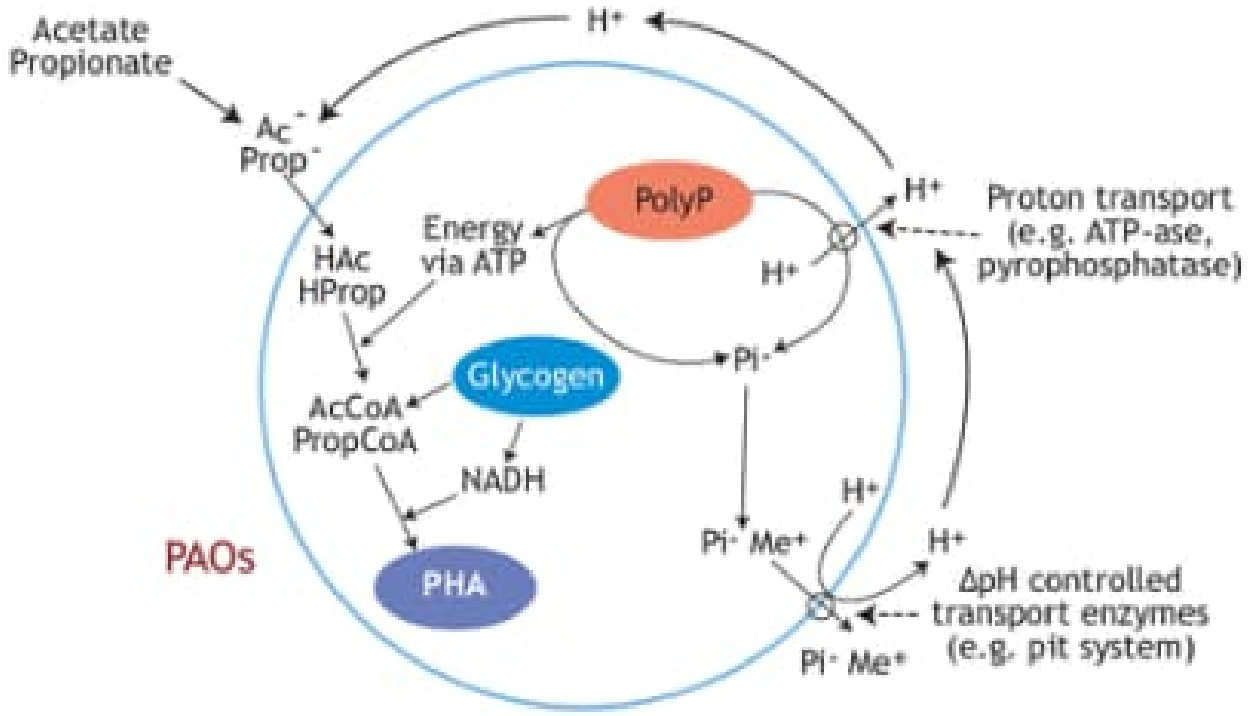
Hydrolysis
Fermentation
COD removal including 2-step denitrification
Anoxic methylotrophs
2-step nitrification
Enhanced biological phosphorus removal (based on Barker-Dold approach)
Temperature sensitvity
Precipitation
Chemical P removal (based on SCM approach)
Anaerobic digestion
Glycogen accumulating organisms

Note! More focused models exist with 4-step denitrification or including N_2O production

BioP

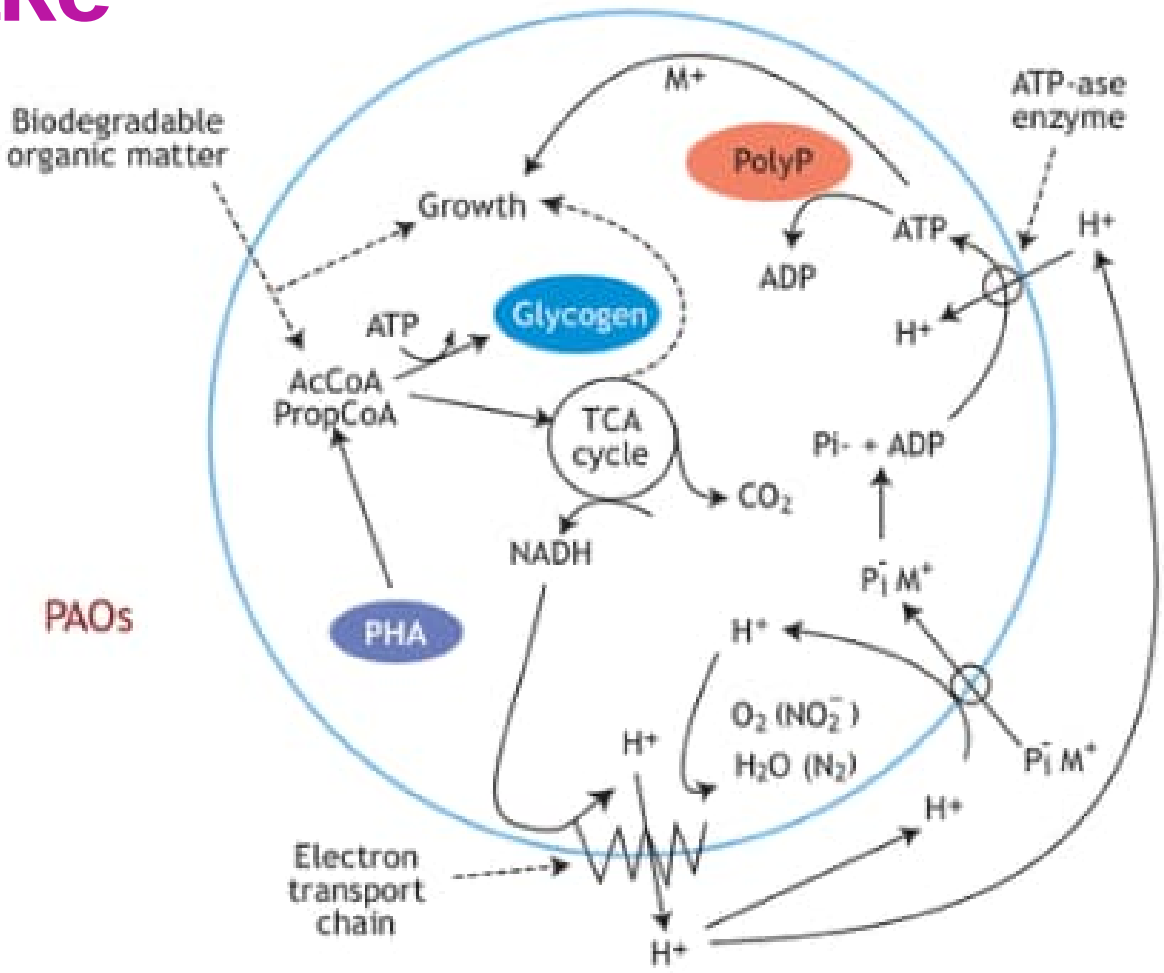

Phosphate (dissolved)
org.matter
energy
PHB, PHV
poly-P
phosphates
ANAEROBIC
CO2+water
energy
PHB, PHV
poly-P
phosphates
AEROBIC

Metabolism of bioP: Anaerobic VFA sequestration



Biological wastewater treatment
Henze, Mogens; Loosdrecht, Mark C. M. van; Ekama, George A.; Brdjanovic, Damir Publisher IWA Publishing

Metabolism of bioP: Aerobic P uptake



Biological wastewater treatment
Henze, Mogens; Loosdrecht, Mark C. M. van; Ekama, George A.; Brdjanovic, Damir Publisher IWA Publishing

Modeling bioP

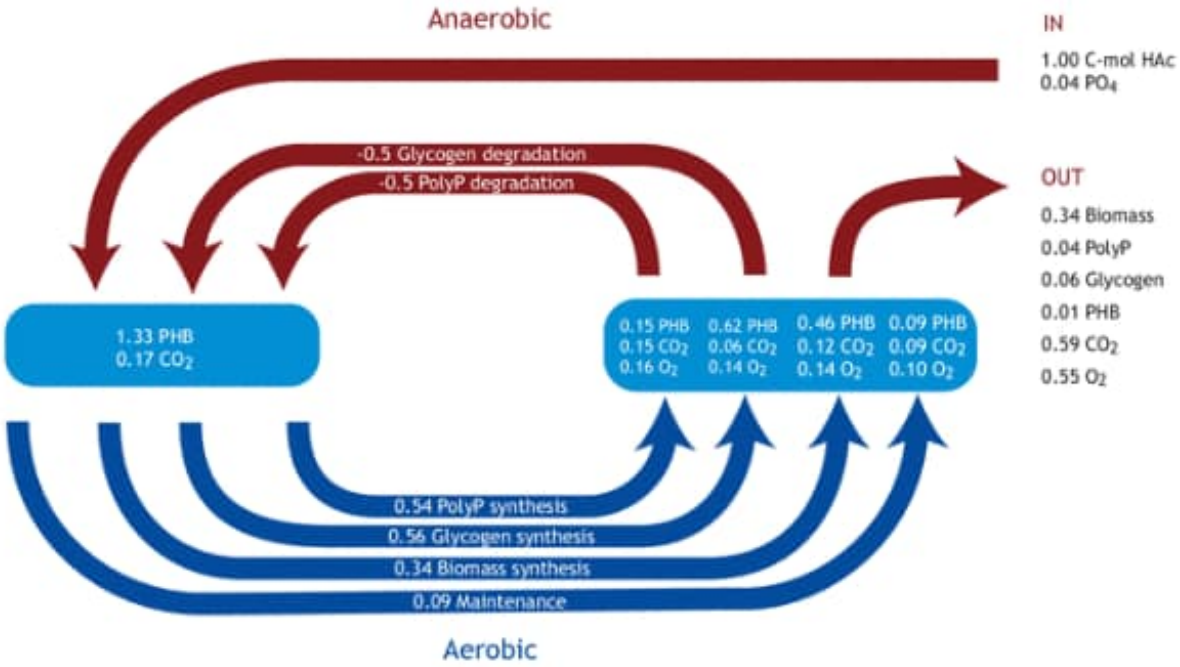
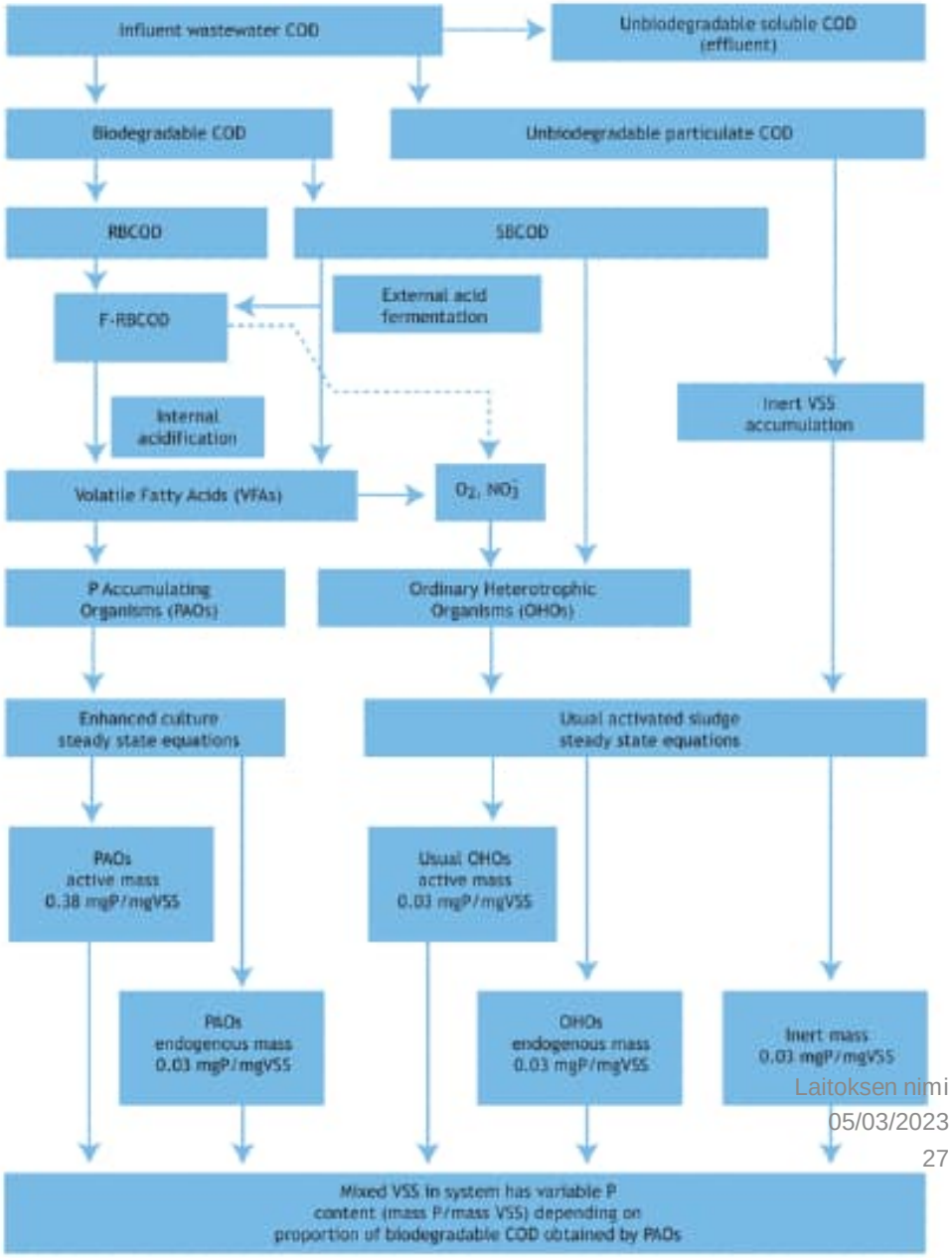


Figure 7.9 Quantitative model for PAOs subjected to anaerobic and aerobic conditions (adapted from Smolders *et al.*, 1994b). Each C-mol acetate corresponds to 0.5 mol of acetate. For acetate, 1 C-mol thus corresponds to 32 gCOD. All other carbon compound concentrations are expressed in C-mol units.

Effect of influent characteristics

Follow *e.g.* unbiodegradable COD and RBOC in the scheme



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Anaerobic digestion